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REMARKS

Applicant appreciates Examiner's thorough review of the Application and the indication of allowable subject matter. Reconsideration and allowance of all claims are respectfully requested. By this amendment, Claims 1, 8, 11, 25, and 33 are amended. No new matter has been added by the amendments. To further distinguish over the references, Claim 1 has been amended to incorporate the subject matter of dependent Claim 2 and Claim 2 has been canceled. Claims 8 and 25 have been amended for clarity and to overcome the rejection under35 U.S.C. 112, second paragraph. Claims 11 and 33 have been amended to make the depend form an allowed claim and place them in condition for allowance. At least Claims 11-12, 13-14, 17, 24, 28-30, 33, and 43-44 are in condition for allowance.

Claims 1 and 3 - 45 are now pending in the application, including independent Claims 1, 17, and 24.

Regarding the objection to Claim 5 found on Pages 2-3 of the Office Action, Applicant has attached a scientific definition of opacity. An opaque object need not have infinite opacity. Rather, as with steel, the opacity may be very high in that most incoming light is reflected, scattered, or absorbed instead of transmitted. However, even steel transmits some incoming light. Because, as noted, some light must be transmitted for photoelasticity to be exhibited, it is clear that Applicant is using the scientific definition of the word in this case, as would be clear to someone of skill in the art. The rejection under 35 U.S.C. 112, first prargraph is therefore improper and should be withdrawn.

Claims 1, 3, 18-19, 26, and 35 are patentable under 35 U.S.C. 102(b) over Flader (U.S. Serial No. 3,373,652).

For an invention to be anticipated, it must be demonstrated that each and every element of the claimed invention is present in the "four corners" of a single prior art, either expressly described therein or under the principle of inherency. Lewmar Marine Inc. v Barient Inc., 3 USPQ2d 1766, 1767-1768 (Fed. Cir. 1987) (emphasis added). The absence from a prior art reference of any claimed element negates anticipation. Kloster Speedsteel AB v. Crucible, Inc., 230 USPQ 81, 84 (Fed. Cir. 1986).

Independent Claim 1

Flader is a polariscope apparatus for determining stress in photoelastic materials and teaches upright polarization 12 and analyzer 13 plates on either side of a structural model 15 being tested with a load 16. Independent Claim 1 as amended differs from Flader at least in that it teaches deformable photoelastic material molded into shapes, wherein the shapes are geometric shapes, flexible sheets, prisms, lenses, wedges, cubes, pyramids, amorphous forms, animal or dinosaur shapes. Flader does not teach or suggest this feature.

The Examiner cites to elements 46 and 47 of Flader as teaching this limitation. Elements 46 and 47 are described as "intermediate diagonal lengths" and do not appear to read on the present invention. Applicant requests that the Examiner explain how elements 46 and 47 read on the claimed invention. Flader teaches the examination of stress in a structural model under loading (Col. 4, ll. 16-44) and not a deformable photoelastic device for amusement and stimulation.

Because Flader fails to teach each and every element of Claim 1, the rejection of Claim 1 under 35 U.S.C. 102(b) is improper and should be withdrawn.

Dependent Claims 3, 18-19, 26 and 35

Dependent Claims 3, 18-19, 26, and 35 depend from and share the patentable features of Claim 1 and add further patentable limitations. Examples are given below.

Claim 3

Claim 3 adds that the photoelastic material is transparent. Flader does not teach or suggest this feature. The Examiner cites to Col. 2, lines 35-38 as teaching this limitation. However, this passage does not refer to the device of Flader but to a special method of observing the effect of loading on a structural model, which is presumably prior art. Flader does not teach the elements arranged as required by the claim. In re Bond, 910 F.2d 831, 15 USPQ2d 1566 (Fed. Cir. 1990) (emphasis added).

Claim 18

Claim 18 adds that the one or more polarizing films are separated and supported by posts disposed between the films. Flader does not teach or suggest this feature. The Examiner cites to elements 72, 115, and 117 as the claimed posts. However, element 72 is described as a support member and is clearly not a post (Figure 6) while elements 115 and 117 are drive shafts for rotating the plates 105, 108 in opposite directions through pinion gears 110, 113. The plates are supported by mounting rings 76, 77 attached to support member 72 and not by the drive shafts.

Therefore Flader fails to teach each and every element of each of the claims. For at least the reasons given above, the rejection of Claims 1, 3, 18-19, 26, and 35 under 35 U.S.C. 102(b) over Flader is improper and should be withdrawn.

Claims 4, 7-8, and 36-37 are patentable under 35 U.S.C. 103(a) over Flader (U.S. Serial No. 3,373,652) in view of Zandman (U.S. Serial No. 3,071,502).

"To establish a *prima facie* case of obviousness, three basic criteria must be met. First, there must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings. Second, there must be a reasonable expectation of success. Finally, the prior art reference (or references when combined) must teach or suggest all the claim limitations." *In re Vaeck*, 947 F.2d 488, 20 USPQ2d 1438 (Fed. Cir. 1991) (emphasis added).

Zandman teaches a process for manufacturing photoelastic sheets of constant thickness for application to a given contour without introducing birefringence during application. (Col. 2:5-8).

Dependent Claims 4, 7-8 and 36-37 depend from and share the patentable features of Claim 1 and add further patentable limitations. Examples are given below.

Claim 4

Claim 4 adds that the photoelastic material is translucent. No reference teaches or suggests this feature. The Examiner, allowing that Flader does not teach this limitation, cites to Zandman as teaching this element. However, the lines cited to by the Examiner state only that

"[photoelastic] materials are usually isotropic, transparent or translucent." Thus Zandman teaches only that photoelastic materials may be translucent.

There would have been no motivation or suggestion to combine Flader and Zandman. The Examiner argues that "[i]t would have been obvious to one of ordinary skill in the art at the time of the invention to have the photoelastic material be translucent, in order to take advantage of inherent color properties and remove the need for additional colorizing filters." Applicant cannot agree.

There is no need for additional colorizing filters in Flader. Inherent color properties are not desirable in Flader. The purpose of Flader is to determine the stress in a structural model and not to amuse. Therefore, there would be no motivation to use translucent material in Flader.

Claim 7

Claim 7 adds that the chemical composition of the photoelastic material is variable as long as the material is photoelastic. No reference teaches or suggests this feature. Recognizing that this limitation is not taught or suggested by Flader, the Examiner cites to Zandman as teaching this limitation. However, the cited lines of Zandman have nothing to do with varying chemical composition. They refer only to the fact that there are various photoelastic materials. Zandman does not teach or suggest the use of any photoelastic material of varying chemical composition.

Furthermore, there would have been no motivation or suggestion to combine Flader and Zandman. The Examiner argues that "[i]t would have been obvious to one of ordinary skill in the art at the time of the invention to have the chemical composition of the photoelastic material is

variable as long as the material is photoelastic, in order to use a material that is best suited to the use of the device." Applicant cannot agree.

This motivation is found nowhere in the art and there is no reason to believe that a material of variable chemical composition would be in any way desirable in Flader. The Examiner's suggestion that a variable chemical composition would be desirable and allow for use of a material "best suited" to use of the Flader device is conclusory and unsupported by any evidence. As the Federal Circuit has held, "a finding of motivation... is a factual question that cannot be resolved on 'subjective belief and unknown authority'... 'the Board must point to some concrete evidence in the record in support' of them." In re Beasley, Civ. App. 04-1225, slip op. at 10, 2004 WL 2793170 (Fed. Cir. Dec. 7, 2004) (unpublished) (citations omitted).

Claim 8

No reference teaches or suggests this feature. Recognizing that this limitation is not taught or suggested by Flader, the Examiner cites to Zandman as teaching this limitation. However, the lines cited to in Zandman merely refer only to the fact that there are various photoelastic materials. These lines have nothing to do with a variable modulus of elasticity. Zandman does not teach or suggest the use of any photoelastic material of varyiable modulus of elasticity. The Examiner argues that "Zandman teaches using different materials, each of which inherently have a different modulus of elasticity." However, nowhere does Zandman teach or suggest using two or more materials together, nor does Examiner cite to any support in Zandman.

Furthermore, there would have been no motivation or suggestion to combine Flader and Zandman. The Examiner argues that "[i]t would have been obvious to one of ordinary skill in the

art at the time of the invention to have the modulus of elasticity is variable, in order to create different internal stress lines." Applicant cannot agree. A *prima facie* case of obviousness requires desirability. As the Federal Circuit has stated, "[t]rade-offs often concern what is feasible, not what is, on balance, desirable. Motivation to combine requires the latter." Winner Int'l Royalty Corp. v. Wang, 53 USPQ2d 1580, 1587 (Fed. Cir.). The record does not indicate that different internal stress lines created by a variable modulus of elasticity would be desirable in Flader.

Claim 36

Claim 36 and adds an applied photoelastic coating. The Examiner, allowing that Flader does not teach or suggest this limitation, cites to Zandman as teaching this feature. However, there would be no motivation for such a combination, considering that Flader teaches a structural model made of photoelastic material. The Examiner argues that "[i]t would have been obvious to one of ordinary skill in the art at the time of the invention to have an applied photoelastic coating, in order to examine the stress of an intricate or complex surface." Applicant cannot agree. Flader uses a small model made of photoelastic material, which already allows for the examination of the stress of an intricate or complex surface. Adding or substituting a photoelastic coating would not be desirable.

Therefore the references fail to teach or suggest all the claim limitations of each of the claims. For at least the reasons given above, the rejection of Claims 4, 7-8, and 36-37 under 35 U.S.C. 103(a) over Flader in view of Zandman is improper and should be withdrawn.

Claims 6, 15-16, 38-40, and 45 are patentable under 35 U.S.C. 103(a) over Flader (U.S. Serial No. 3,373,652) in view of Rasmussen (U.S. Serial No. 6,944,983).

Rasmussen teaches a device for providing a color-changing display. A light source transmits light through a first polarizing layer, a bi-refringent layer, and a second polarizing layer. One of the layers rotates to produce a polychromatic effect. (Col. 3, ll. 57-63)

Dependent Claims 6, 15-16, 38-40, and 45 depend from and share the patentable features of Claim 1 and add further patentable limitations. Examples are given below.

Claim 6

Claim 6 adds that different regions of the photoelastic material differ in the amount of light they transmit. No reference teaches or suggests this feature. The Examiner, allowing that Flader does not teach or suggest this limitation, cites to Rasmussen as teaching this feature. However, the lines cited to by the Examiner read: "By applying numerous layers of varied thickness and orientation, you can further modify the local index of refraction and corresponding patterns of birefringence." The index of refraction affects how much light rays change direction when they cross the interface from air to the material, not how much light is transmitted.

Furthermore, there would have been no motivation or suggestion to combine Flader and Rasmussen. The Examiner argues that "[i]t would have been obvious to one of ordinary skill in the art at the time of the invention to have different regions of the photoelastic material differ in the amount of light they transmit, in order to further modify the local birefringence patterns." Applicant cannot agree. Modifying birefringence patterns would not be desirable in Flader,

which seeks to determine the stress in a structural model.

Claim 15

Claim 15 adds that the shape is a prism, lens or wedge for creating various optical effects. No reference teaches or suggests this feature. The Examiner, allowing that Flader does not teach or suggest this limitation, cites to Rasmussen as teaching this feature. The Examiner argues that "[i]t would have been obvious to one of ordinary skill in the art at the time of the invention to have the shape be a prism, lens or wedge for creating optical effects, in order to avoid a direct view of the light source." Applicant cannot agree. Flader already avoids a direct view of the light source because polarizing films and the structural model are between the light source and the viewer. Therefore there would be no motivation to combine the references.

Claim 16

Claim 16 adds that the one or more polarizing films are attached on one or more outer surfaces on the photoelastic material. No reference teaches or suggests this feature. The Examiner, allowing that Flader does not teach or suggest this limitation, cites to Rasmussen as teaching this feature. However, the lines cited to by the Examiner refer to layers of "oriented polymer film" which create birefringence. They do not address photoelastic material or polarizing films.

Furthermore, there would have been no motivation or suggestion to combine Flader and Rasmussen. The Examiner argues that "[i]t would have been obvious to one of ordinary skill in the art at the time of the invention to have the one or more polarizing films be attached to one or

more outer surface on the photoelastic material, in order to allow the use of any desired shape." Applicant cannot agree. Applicant requests that the Examiner explain how polarizing films attached to an outer surface allow for the use of any desired shape. It appears that Flader already can use essentially any desired shape within the gap between plates.

Claim 38

Claim 38 adds an opaque object or a mirrored surface below, a characteristic of or embedded within the transparent or translucent photoelastic material. The Examiner, allowing that Flader does not teach or suggest this limitation, cites to Rasmussen as teaching this feature. However, there would be no motivation to combine Flader and Rasmussen. The Examiner argues that "[i]t would have been obvious to one of ordinary skill in the art at the time of the invention to have an opaque object or a mirrored surface below, a characteristic of or embedded within the transparent or translucent photoelastic material, in order to increase the visibility of the internal stress patterns." Applicant cannot agree. No such motivation is found in the references. The Examiner has not supplied any evidence to support his conclusion that this limitation necessarily leads to increased visibility of internal stress patterns.

Claim 45

Claim 45 adds that transparent or translucent protective coatings are applied over outer surfaces of the photoelastic material. No reference teaches or suggests this feature. The Examiner, allowing that Flader does not teach or suggest this limitation, cites to Rasmussen as teaching this feature. However, the lines cited to by the Examiner state that "bi-refringent coating may be places on the transparent or translucent sculpture described below as a

preliminary coating prior to the polarizing coating." This does not appear to have anything to do with a transparent or translucent protective coverin over the surface of a photoelastic material.

Therefore the references fail to teach or suggest all the claim limitations of each of the claims. For at least the reasons given above, the rejection of Claims 6, 15-16, 38-40, and 45 under 35 U.S.C. 103(a) over Flader in view of Rasmussen is improper and should be withdrawn.

Claims 9 and 25 are patentable under 35 U.S.C. 103(a) over Flader (U.S. Serial No. 3,373,652).

Dependent Claims 6, 15-16, 38-40, and 45 depend from and share the patentable features of Claim 1 and add further patentable limitations. Examples are given below.

Claim 9

Claim 9 adds that the photoelastic material is a single color. No reference teaches or suggests this feature. The Examiner, allowing that Flader does not explicitly teach or suggest this limitation, relies on the principle of inherency. However, MPEP 2112 (IV) states that "In relying upon the theory of inherency, the examiner must provide a basis in fact and/or technical reasoning to reasonably support the determination that the allegedly inherent characteristic necessarily flows from the teachings of the applied prior art." Ex parte Levy, 17 USPQ2d 1461, 1464 (Bd. Pat. App. & Inter. 1990) (emphasis in original)

"The fact that a certain result or characteristic may occur or be present in the prior art is not sufficient to establish the inherency of that result or characteristic... "Inherency... may not be established by probabilities or possibilities. The mere fact that a certain thing may result from a given set of circumstances is not sufficient.' " *In re Robertson*, 169 F.3d 743, 745, 49 USPQ2d 1949, 1950-51 (Fed. Cir. 1999) (citations omitted)

It is simply not true that in the absence of dyes or additives, any material is of a single color. For example, a material that has been abraded or exposed to a temperature gradient may have multiple colors.

Claim 25

Claim 25 adds objects embedded in the photoelastic material, wherein a thin air interface between the embedded objects and the photoelastic material creates interference patterns of light. No reference teaches or suggests this feature. The Examiner, allowing that Flader does not explicitly teach or suggest this limitation, relies on the principle of inherency. However, Flader does not teach embedded objects or a thin air interface between the embedded objects and a phtooelastic material at all. Indeed, the Examiner does not assert otherwise.

Therefore the references fail to teach or suggest all the claim limitations of each of the claims. For at least the reasons given above, the rejection of Claims 9 and 25 under 35 U.S.C. 103(a) over Flader is improper and should be withdrawn.

Claims 10 and 31-32 are patentable under 35 U.S.C. 103(a) over Flader (U.S. Serial No.

3,373,652) in view of Frocht (U.S. Serial No. 2,070,787).

Frocht teaches a method of displaying changing light effects to enhance the attractiveness or direct attention to a primary object to be observed. (Col. 1, ll. 1-7) The object is illuminated with colored light effects with a constant changing and shifting of patterns showing areas of different colors, changing from one color to another along beautiful and continuously merging lines. (Col. 1, ll. 25-35)

Dependent Claims 10 and 31-32 depend from and share the patentable features of Claim 1 and add further patentable limitations. Examples are given below.

Claim 10

Claim 10 adds that the photoelastic material is different colors in different regions. No reference teaches or suggests this feature. The Examiner, allowing that Flader does not teach or suggest this limitation, cites to Frocht as teaching this feature. However, Frocht clearly teaches that it is the light produced that has varying colors, and not a photoelastic material (Page 1).

Furthermore, there would have been no motivation or suggestion to combine Flader and Frocht. The Examiner argues that "[i]t would have been obvious to one of ordinary skill in the art at the time of the invention to have the photoelastic material be different colors in different regions, in order to create an attractive and attention-gathering display." Applicant cannot agree. Flader would not be improved by an attractive and attention-gathering display, as its purpose is to determine stress in a structural model.

Claim 32

Claim 32 adds that combinations of manual manipulation, springs, strings, elastic bands, clamps and force-applying devices are used to affect stress patterns. No reference teaches or suggests this feature. The Examiner, allowing that Flader does not teach or suggest this limitation, cites to Frocht as teaching this feature. However, Frocht appears to use only a single force-applying device.

Therefore the references fail to teach or suggest all the claim limitations of each of the claims. For at least the reasons given above, the rejection of Claims 10 and 31-32 under 35 U.S.C. 103(a) over Flader in view of Frocht is improper and should be withdrawn.

Claims 20, 23, 27, and 41 are patentable under 35 U.S.C. 103(a) over Flader (U.S. Serial No. 3,373,652) in view of Cotterman (U.S. Invention Registration H76).

Cotterman teaches an instructional polariscope that can be disassembled and reassembled. Dependent Claims 20, 23, 27, and 41depend from and share the patentable features of Claim 1 and add further patentable limitations. Examples are given below.

Claim 20

Claim 20 adds that the one or more polarizing films are disposed on individual stands for flexibility in viewing. The Examiner, allowing that Flader does not teach or suggest this limitation, cites to Cotterman as teaching this element. However, there would have been no motivation to combine Cotterman with Flader. Flader uses a different structure and it is not clear how or if the structure of Cotterman could be incorporated therein. Cotterman and Flader, taken

as a whole, do not render the claimed invention as a whole obvious.

The Examiner argues that "[i]t would have been obvious to one of ordinary skill in the art at the time of the invention to have the one or more polarizing films be disposed on individual stands for flexibility of viewing, in order to allow the device to adjust the polarization (e.g. plane vs. circular)." Applicant cannot agree. It is the quarter-wave plates that make the polariscope plane or circular, as explained in the lines cited to by the Examiner, and not the individual stands.

Claim 23

Claim 23 adds that the one or more polarized films are polaroid films rotated with respect to one another for increasing or decreasing the amount of light passing through the photoelastic object. No reference teaches or suggests this feature. The Examiner, allowing that Flader does not teach or suggest this limitation, cites to Cotterman as teaching this feature. However, Cotterman teaches that the quarter-wave plates are Polaroid Wave Retarders, not that the polarized films are polaroid films.

Claim 27

Claim 27 adds that stress patterns are affected by manual manipulation of the photoelastic material. No reference teaches or suggests this feature. The Examiner, allowing that Flader does not teach or suggest this limitation, cites to Cotterman as teaching this feature. However, does not teach manual manipulation.

Therefore the references fail to teach or suggest all the claim limitations of each of the

claims. For at least the reasons given above, the rejection of Claims 20, 23, 27 and 41 under 35 U.S.C. 103(a) over Flader in view of Cotterman is improper and should be withdrawn.

Claim 34 is patentable under 35 U.S.C. 103(a) over Flader (U.S. Serial No. 3,373,652) in view of Payne et al (U.S. Serial No. 3,331,236).

Payne teaches an apparatus for testing protective helmets under whiplash conditions. (Abstract) A test helmet on a lever arm swings about an axis and strikes the anvil for testing. (Figures) Dependent Claim 34 depends from and shares the patentable features of Claim 1 and adds that a sharp object is used to create stress patterns by contacting the photoelastic material. No reference teaches or suggests this feature. The Examiner, allowing that Flader does not teach or suggest this limitation, cites to Payne as teaching this feature. However, element 32 of Payne is an impact anvil and not a sharp object.

Furthermore, there would have been no motivation to add the lever arm and anvil of Payne to Flader. Doing so would require an overhall of the Flader device and would bring no apparent benefit. Flader is for measuring stress on structural models.

Therefore the references fail to teach or suggest all the claim limitations of Claim 34. For at least the reasons given above, the rejection of Claim 34 under 35 U.S.C. 103(a) over Flader in view of Payne is improper and should be withdrawn.

Claim 42 is patentable under 35 U.S.C. 103(a) over Flader (U.S. Serial No. 3,373,652) in view of Issa and Maamoun.

Issa teaches that acrylic seems to be an ideal material for isodyne photoelastic analysis. (Conclusion) Dependent Claim 42 depends from and shares the patentable features of Claim 1 and adds further patentable limitations. Claim 42 adds that fixed, permanent fringes are fixed within the photoelastic object through curing techniques and permanent deformation strategies. No reference teaches or suggests this feature. Allowing that Flader does not teach or suggest this limitation, the Examiner cites to Issa as providing this element. However, the section of Issa cited to by the Examiner does not appear to reference fixed, permanent fringes, curing techniques, or permanent deformation strategies. Furthermore, Applicant does not understand the Examiner's argument that permanent fringes would allow the use of Plexiglass and requests further explanation.

Therefore the references fail to teach or suggest all the claim limitations of Claim 42. For at least the reasons given above, the rejection of Claim 42 under 35 U.S.C. 103(a) over Flader in view of Issa is improper and should be withdrawn.

Claims 1 and 21-22 are patentable under 35 U.S.C. 103(a) over Kreibel (U.S. Serial No. 2,120,365).

Kriebel teaches an analyzer and tint plate in intimate contact on a spectacle frame, along with an article of manufacture, a light source, and a polarizing element. Claim 1 as amended teaches deformable photoelastic material molded into shapes, wherein the shapes are geometric shapes, flexible sheets, prisms, lenses, wedges, cubes, pyramids, amorphous forms,

animal or dinosaur shapes. No references teach or suggest this limitation, including Kriebel, and the Examiner does not argue otherwise.

Dependent claims 21-22 depend from and share the patentable features of Claim 1 and add further patentable limitations.

For example, Claim 21 adds a polarized light source for passing light through the photoelastic material and then through a pair of polarized glasses. No references teach or suggest these features. The Examiner, allowing that Flader does not teach or suggest the limitations, cites to Kriebel as teaching this element. However, Kriebel does not teach a polarized light source, but a normal light source and a separate polarizing element. The Specification clearly distinguishes between embodiments with normal light sources and polarizing films and embodiments with polarized light sources. Therefore the meaning of the claim is clear and different from Kriebel.

The references fail to teach or suggest all the claim limitations of Claims 1 and 21-22. For at least the reasons given above, the rejection of Claims 1 and 21-22 under 35 U.S.C. 103(a) over Flader in view of Kriebel is improper and should be withdrawn.

CONCLUSION

Reconsiderations and Allowance are requested.

Respectfully,

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An opaque substance transmits very little light, and therefore reflects, scatters, or absorbs most of it. Both mirrors and carbon black are opaque. Opacity depends on the frequency of the light being considered. For instance, some kinds of glass, while transparent in the visual range, are largely opaque to ultraviolet light. More extreme frequency-dependence is visible in the absorption lines of cold gases. In general, a material tends to emit light in the same proportions as it absorbs it.

Contents

Definition

The opacity κ_ν gives the rate of absorption (or extinction), which is the fraction of the intensity I_ν, of the radiation that is absorbed or scattered per unit distance along a ray of propagation:

$$\frac{\partial I_\nu}{\partial x} = -I_\nu \kappa_\nu.$$

For a given medium it has a numerical value that may range between 0 and infinity. It is also called the absorption coefficient (see also extinction coefficient). In general κ_ν depends on the frequency ν of the radiation, as well as the density, temperature, and composition of the medium. The mean free path is the distance a photon travels in the medium before absorption or scattering is defined as $1 / \kappa_\nu$. The notation κ_λ is the opacity described as a function of wavelength λ. While many materials are very opaque (steel in visible light having near-infinite opacity), and others very transparent (air in visible light having near-zero opacity), so that opacity often seems to be a boolean property, many others (such as water) have intermediate opacity.

In astronomy and planetary imaging fields, tau, the optical depth, defines the opacity: zero indicates transparent and higher numbers indicate more and more opaque in an inverse exponential fashion, for example a tau of 1 indicates 36 percent of the light passes ($e^{-1} = 0.36$), and a Tau of 5 indicates less than 1 percent passes ($e^{-5} = 0.0067$).[1]

In astrophysics and plasma physics "opacity", or absorption coefficient, κ_ν is defined so that $\kappa_\nu \rho I_\nu d\nu d\Omega$ gives the corresponding energy absorbed per unit volume per unit time from a beam of given intensity I_ν in a medium of density ρ (thus κ_ν is measured in $\mathrm{cm^2 g^{-1}}$). The optical depth τ_ν along the propagation direction is then $d\tau_\nu = \kappa_\nu \rho ds$, where ds is the distance along this direction. It is customary to define the average opacity, calculated using a certain weighting scheme. **Planck opacity** uses normalized Planck black body radiation energy density distribution as the weighting function, and averages κ_ν directly. **Rosseland opacity**, on the other hand, uses a temperature derivative of Planck distribution (normalized) as the weighting function, and averages κ_ν^{-1},

$$\frac{1}{\kappa} = \frac{\int_0^\infty \kappa_\nu^{-1} u(\nu, T) d\nu}{\int_0^\infty u(\nu, T) d\nu}.$$

The photon mean free path is $\lambda_\nu = (\kappa_\nu \rho)^{-1}$. The Rosseland opacity is derived in the diffusion approximation to the radiative transport equation. It is valid whenever the radiation field is isotropic over distances comparable to or less than a radiation mean free path, such as in local thermal equilibrium. In practice, the mean opacity for Thomson electron scattering is $\kappa_{es} = 0.40 \mathrm{cm^2 g^{-1}}$ and for nonrelativistic thermal bremsstrahlung, or free-free transitions, it is $\kappa_{ff}(\rho, T) = 0.64 \times 10^{23} (\rho[\mathrm{g\ cm^{-3}}]) (T[\mathrm{K}])^{-7/2} \mathrm{cm^2 g^{-1}}$.[2] The Rosseland mean absorption coefficient including both scattering and absorption (also called the extinction coefficient) is

$$\frac{1}{\kappa} = \frac{\int_0^\infty (\kappa_{\nu,es} + \kappa_{\nu,ff})^{-1} u(\nu, T) d\nu}{\int_0^\infty u(\nu, T) d\nu}.$$ [3]